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Interproximal Grooving in the Atapuerca-SH Hominid Dentitions

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ABSTRACT The dental sample recovered from the Sima de los Huesos (SH) Middle Pleistocene cave site of the Sierra de Atapuerca (Spain) includes 296 specimens. Interproximal wear grooves have been observed in 20 maxillary and mandibular posterior teeth belonging to at least five of the 32 individuals identified so far in the SH hypodigm. Interproximal grooving affected only the adults, and at an age between 25 and 40 years. The appearance, morphology, and location pattern of the SH wear grooves are similar to those reported in other fossil hominids and in more recent human populations. Two alternative proposals, the toothpicking and the fiber or sinew processing hypotheses, compete for explaining the formation of this anomalous wear. The characteristics observed in the wear grooves of the SH teeth are compatible only with the habitual probing of interdental spaces by means of hard and inflexible objects. Dietary grit may also have contributed to the abrasion of the root walls during the motion of the dental probes. Am. J. Phys. Anthropol. 102:369–376, 1997.

The presence of interproximal grooving in human fossil teeth from the Sima de los Huesos (SH) Middle Pleistocene cave site of the Sierra de Atapuerca (Burgos, Spain) was first noted by Pérez et al. (1982) and Bermúdez de Castro and Arsuaga (1983). In these reports, the authors described interproximal grooves located at the mesial and distal root walls, just below the cementum enamel junction (CEJ), of one isolated mandibular first molar (LM1), AT-14, and one isolated LM2 (AT-11). These teeth were recovered in SH together with 17 more human fossil remains, which include the mandible AT-1, the mandibular fragments AT-2 and AT-3, and 11 more isolated teeth, during the excavation conducted in 1976 by T. Torres (Aguirre et al., 1976). Pérez et al. (1982) and Bermúdez de Castro and Arsuaga (1983) concluded that the wear grooves of the Atapuerca-SH teeth were produced antemortem by means of a hard object, probably acting as a toothpick. Thus, these authors agree with one of the hypotheses previously formulated to explain the presence of similar grooves in other hominid fossils and recent human populations (Berryman et al., 1979; Frey, 1933; Grilleto, 1977; Hartweg, 1945; Janssens, 1970; Martin, 1923; Patte, 1941; Siffre, 1911; Ubelaker et al., 1969).

A search of the relevant literature reveals that interproximal grooving is a phenomenon observed in fossil hominids from diverse sites, spread across Africa, Asia, and Europe over the entire Pleistocene. Even more, the earliest known occurrence of this

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anomalous wear was reported by Boaz and Howell (1977) in the right and left maxillary third premolars (UP3s) of a hominid dentition (L.894) attributed to the genus *Homo*, from the middle of the Unit G-28 of the Shungura Formation. Potassium/argon dates indicated an age between 1.93 ± 0.1 and 1.84 ± 0.09 Ma. for this hominid (Boaz and Howell, 1977). Other occurrences in fossil hominids include those of the Lower Pleistocene mandible from Konso Gardula in Ethiopia (Asfaw et al., 1993), the specimens ZK 38 (LM2) and ZK O/I (UM2) from Zhoukoudian (Weidenreich, 1937), the isolated UM2 from Rabat (Senyürek, 1940), the LM2 of the mandibular fragment AT76-T1H from the TG-TN complex of the Sierra de Atapuerca (Bermúdez de Castro and Rosas, 1992), the LM1s and LM2s of la Quina 5 (Siffre, 1911; Martin, 1923), the specimen eleven (UM3) from Hortus (de Lumley, 1973), the UM1 of la Ferrasie 2 and the isolated UM3 from La Chapelle-aux-Saints (Bermúdez de Castro and Pérez, 1986), as well as those of 14 Krapina Neandertal teeth (Frayer and Russell, 1987). We have also observed interproximal grooving in the north African Middle Pleistocene mandible 3 from Thigenif. This specimen exhibits a conspicuous wear groove affecting the buccal-distal corner of the left M1 and M2. It was not possible to examine adequately the mesial surfaces of these teeth to detect the presumed presence of some polishing, but certainly the right M1 and M2 are not affected by interproximal grooving.

There is also a widespread documentation about interproximal grooving in Upper Paleolithic (Formicola, 1988; Frayer and Russell, 1987; Frayer, 1991), Mesolithic (Bermúdez de Castro and Pérez, 1986; Frayer and Russell, 1987), Neolithic (Hartweg, 1945; Patte, 1941), and more recent human skeletal populations (Bermúdez de Castro and Arsuaga, 1983; Berryman et al., 1979; Brown and Molnar, 1990; Campbell, 1925; Grilleto, 1977; Larsen, 1985; Schulz, 1977; Ubelaker et al., 1969; Wallace, 1974).

From 1984 to 1995, systematic excavations have enlarged the SH human hypodigm to near 2,000 human fossil remains (Arsuaga et al., 1993). This collection includes now a total of 296 teeth belonging to a minimum of 32 individuals (Bermúdez de Castro and Nicolás, 1997). We report here the presence of interproximal wear grooves in several more specimens of the SH dental sample. A brief discussion on the etiology of this wear pattern is also presented.

MATERIALS AND METHODS

The current human dental sample from the site SH (up to the 1995 excavation) includes 123 permanent maxillary teeth (27 in situ), 171 permanent mandibular teeth (64 in situ) and two deciduous teeth (Table 1). The mesial and distal surfaces of the isolated teeth and, when it was possible, the mesial and/or distal surfaces of some in situ teeth, were examined using a low-power binocular microscope. The mesial and distal root walls of some teeth implanted in the jaws cannot be easily observed by eye, and the presence of at least some degree of polishing may pass unnoticed. However, since the presence of interproximal grooving seems to be closely related to certain degree of denudation of the roots (see below), this problem concerns only the in situ teeth of adults. In addition, scanning electron microscope (SEM) images (Philips XL 20) were directly obtained, using low voltage, from one specimen (AT-810).

In order to estimate the degree of denudation of the roots of the in situ teeth, the distance from the CEJ to the alveolar crest (AC) was measured with a dial caliper to an accuracy of 0.1 mm at the lingual and buccal aspects of the M1s and M2s. Since the alveolar border is frequently broken away in some sections of all specimens, it was not possible to use a fixed reference point to take this measurement. As an approximation to the degree of occlusal wear of the specimens affected by interproximal grooving, we also indicate the pattern of dentine exposed in M1 and M2 following Murphy (1959).

RESULTS

The inventory of the Atapuerca-SH grooved teeth is presented in Table 2. A total of 20 specimens showed mesial and/or distal grooves. These teeth belong to a minimum of five individuals (IV, V, XXI, XXVII, and XXXI), and a maximum of six individuals. In most cases the grooves are easily identified

TABLE 1. Number within each tooth class in the Atapuerca-SH dental hypodigm recovered until the 1995 excavation

	dc	dm2	I1	I2	C	P3	P4	M1	M2	M3	Total
Maxillary											
I.S.[1]	—	—	1	0	0	3	3	8	7	5	27
I.[2]	—	—	18	9	11	6	9	11	16	16	96
Total	—	—	19	9	11	9	12	19	23	21	123
Mandibular											
I.S.	—	—	0	2	2	8	7	14	17	14	64
I.	1	1	13	17	14	10	16	16	8	13	109
Total	1	1	13	19	16	18	23	30	25	27	173
Grand total											296

[1] I.S., in situ teeth.
[2] I., isolated teeth.

TABLE 2. List of artificially grooved teeth at Atapuerca-SH

Inventory number	Anatomical part	Grooved teeth	Dentine exposure[1]		CEJ-AC distance[2] (min.–max.)	Location of grooves	Individual	Estimated age at death[3] (yr)	Nongrooved in situ teeth
			M1	M2					
AT-972	Mandible	Left LP4				Distal	XXVII	26–30	Right P3-M2
		Left LM1	d		4.4–4.6	Mesial	XXVII		Left P3 and M3
AT-951	Isolated tooth	Left UM3				Mesial	XXXI	26–30	
AT-74	Isolated tooth	Left LP4				Distal	IV	26–30	
AT-14	Isolated tooth	Left LM1	e		5.6–5.7	Mesial and distal	IV		
AT-250	Left mandibular body	Left LM2		d		Mesial	IV		Left P3 and M3
AT-793	Right mandibular body	Right LM2		d	4.2–5.6	Mesial	IV		Right M3
AT-810	Isolated tooth	Left UM2		d		Mesial & distal	IV		
AT-940	Isolated tooth	Right UP4				Mesial & distal	V	30–40	
AT-948	Isolated tooth	Right UM3				Mesial	V		
AT-1130	Maxillary fragment	Right UM1	f		4.0–5.1	Mesial and distal	V		
		Right UM2		f		Mesial and distal	V		
AT-888	Mandible	Right and left LM1	f		4.5–7.1	Mesial and distal	XXI	30–40	Right and left
		Right and left LM2		f		Mesial	XXI		P3, P4 and M3
AT-700	Cranium	Right and left UM1	f		3.9–6.4	Mesial and distal	XXI		Right I1 and M3
		Right UM2		f		Mesial	XXI		Left M3
AT-11	Isolated tooth	Left LM2		f		Mesial and distal	—		

[1] According to the Murphy (1959) classification.
[2] Measurement taken at the buccal and lingual aspect of the M1s (preferably) or M2s.
[3] According to Bermúdez de Castro and Nicolás (1997).

by eye, but the UM3 of the individual XXXI shows only an incipient wear groove on the mesial-lingual corner (the zone of transition from the mesial root surface to the lingual root surface). Individual XXXI also includes the mandible AT-950, which exhibits the left and right complete molar series. The presence of at least some polishing in these teeth cannot be confirmed by microscopic observation. The specimen AT-11 (isolated left LM2) exhibits an advanced degree of occlusal wear, and it could belong to individual V. However, we have not additional criteria to include AT-11 in this individual.

The presence of grooved teeth in the Atapuerca-SH dental sample is always associ-

ated to a certain degree of denudation of the roots. Further, all the SH individuals whose CEJ-AC distance at the level of the upper and lower M1s or M2s is greater than 3.2 mm exhibit interproximal grooving. In these individuals, the CEJ-AC distance ranges from 4.0 to 7.1 mm (Table 2). In mandible AT-950 (individual XXXI), the CEJ-AC distance at the level of the M1 is 3.1 mm on the buccal aspect, and 3.0 on the lingual aspect. Since the normal distance from the CEJ to the AC is about 2 mm (Davies and Picton, 1969), the presence of interproximal grooving in the SH hominids requires a denudation of the roots of at least 1 mm.

Furthermore, interproximal grooving does tend to affect the SH individuals with more advanced occlusal tooth wear, however, that is, the oldest individuals. The estimated age-at-death of the individuals IV, XXVII, and XXXI is in the 26–30 year interval, whereas individuals V and XXI probably died during the fourth decade (Bermúdez de Castro and Nicolás, 1997). The mandible AT-888 and cranium AT-700 (individual XXI), as well as the maxilla AT-772 and mandible AT-792 (individual XXVII) probably belonged to males, whereas the mandibles AT-250 + AT-793 (individual IV) and AT-950 (individual XXXI) have been assigned to females (see also Bermúdez de Castro and Nicolás, 1997). Individual V does not include enough material to be accuretely sexed.

Interproximal grooving generally affects only a part of the mesial and distal root walls. From the evidence offered by the SH teeth, this anomalous wear usually begins either at the buccal aspect, or at the lingual aspect of the interproximal surfaces. Then, it progresses towards the middle of the interproximal surface, from where it might reach the opposite border. The width of the grooves also increases with their progressive increase in length, which probably depends on the gradual broadening up of the interdental space. The Atapuerca-SH wear grooves also show a generalized location pattern. Interproximal grooving on the distal face of the lower and upper M2s always involves the buccal-distal corner, and it extends to about midway, never reaching the buccal-lingual corner (Fig. 1A). On the mesial face of the lower and upper M1s and

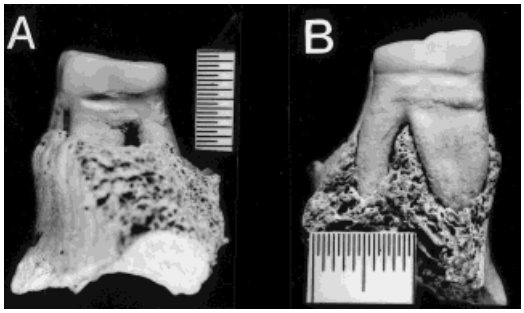

Fig. 1. Interproximal grooves on (**A**) distal face of the right upper second molar of the maxillary fragment AT-1130 (individual V from the SH hominid sample), and (**B**) mesial face of the right upper first molar of the same specimen. Note the presence of dental calculus under the wear grooves.

M2s, the grooves generally affect both the buccal and lingual aspects of the root walls, but without reaching the mesial-buccal and mesial-lingual corners (Fig. 1B). In some cases, such as the mesial face of the UM3, AT-951, and the mesial face of the M2s of the mandible AT-888, interproximal grooving is confined to the lingual aspect of the root walls.

In all cases, the grooves of the Atapuerca-SH teeth are located under the CEJ affecting the cementum, the underlying dentine and very slightly the latest enamel-forming layers of the crown. The morphology of the grooves is similar to that reported and figured in other fossil hominids and recent human populations. Thus, the grooves are buccolingually elongated and generally oval. When the anomalous wear affects a depressed area, such as the broad vertical groove running the mesial or distal roots of the lower molars, an inlet breaks the continuity of the inferior border of the groove. This morphology is observed in the mesial face of AT-14 and in the mesial face of the M1 of AT-1130 (Fig. 1B). When both the mesial and distal faces of two adjacent teeth are involved, there is a characteristic tubular appearance of the grooves. Deposits of dental calculus are often present under the grooves of some specimens (Fig. 1), but these deposits were never observed on the surface of the grooves.

The surface of all grooves observed under magnification exhibit fine parallel scratches running buccolingually. SEM analysis facili-

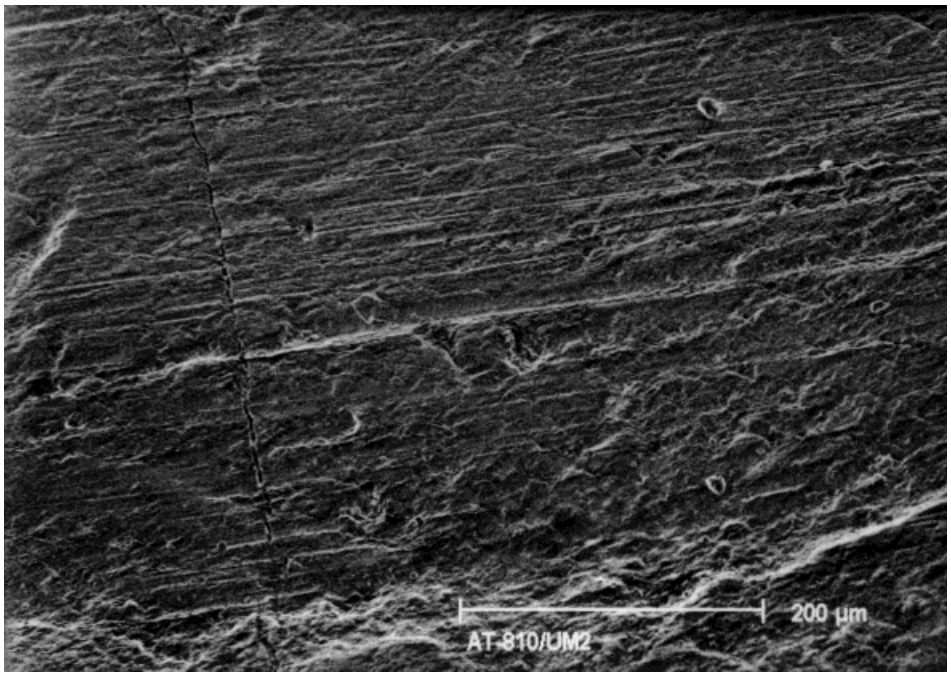

Fig. 2. SEM image of the surface of the mesial wear groove of the upper M2 AT-810 (individual IV from the SH hominid sample). The surface exhibits numerous, generally fine, and parallel striations running buccolingually.

tates the observation of this striation pattern (Fig. 2). Most scratches are parallel to the long axis of the groove, but near the ends of the lesions, the scratches can diverge at low angles from this axis (Fig. 3).

DISCUSSION

Interproximal grooving seems to be a common occurrence in fossil hominids, at least from the end of the Pliocene. It has also been observed in numerous recent human populations of widely different geographical origins. It is important to note the similarity in appearance, size and shape of interproximal grooves observed in posterior teeth by numerous authors. The etiology of this wear pattern has been discussed at length by several workers (i.e., Bermúdez de Castro and Arsuaga, 1983; Berryman et al., 1979; Brown and Molnar, 1990; Frayer and Russell, 1987; Ubelaker et al., 1969). Some hypotheses, such as antemortem erosion (Brothwell, 1963; Campbell, 1925) or abrasion produced by dietary grit mixed with food and drinking water sucked from the vestibule into the oral cavity (Wallace, 1974), are not supported by the similarity in appearance, size and shape of the grooves.

A certain degree of root denudation is a necessary condition for the formation of an interproximal groove. The alveolar bone loss, due to senile atrophy of the bone, periodontitis, and/or continuous tooth eruption (Danenberg et al., 1991), leads to the opening up of a sufficiently wide interdental space to permit the passing of objects between adjacent teeth. If the hardness of the objects is adequate, they may produce a polishing of the cementum and dentine. It is interesting to note that in the mandible Tighenif 3, the CEJ-AC distance at the buccal aspect of the left M1 and M2 ranges between 3 and 4 mm, thus indicating a small degree of denudation of the roots of this specimen. The presence of fine paralell striations scratching the surface of the grooves, which have been reported by some authors (Bermúdez de Castro and Arsuaga, 1983; Boaz and Howell, 1977; Frayer and Russell, 1987; Ubelaker et al., 1969; Wallace, 1974), indicates that hard

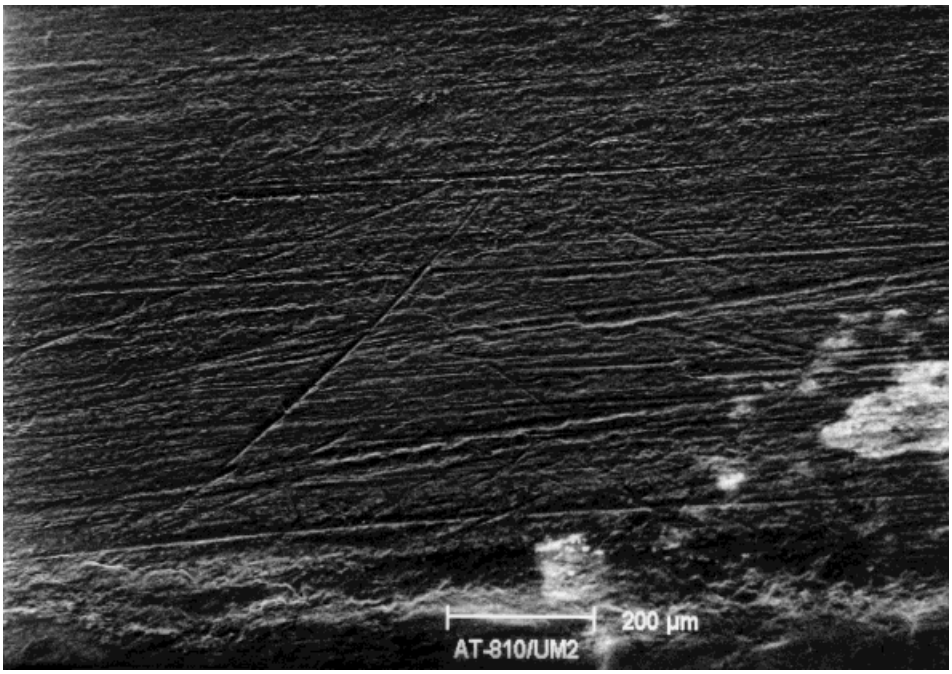

Fig. 3. SEM image of the surface of the mesial wear groove of the upper M2 AT-810. The left side in the picture corresponds to the lingual extreme of the wear groove of this specimen. Near the ends of the lesions, scratches can diverge at low angles from the long axis of the groove.

particles may help to produce the abrasion of the root wall.

In our opinion, the only two reasonable proposals that have been put forward to account for interproximal grooving in posterior teeth are the use of dental probes (toothpicks), and fiber or sinew processing. The latter hypothesis assumes some kind of task activity involving the processing of fibrous material or the stripping of animal sinews between the teeth. This activity seems to be limited to the anterior teeth (Larsen, 1985; Schulz, 1977). However, Brown and Molnar (1990) have suggested that the presence of interproximal grooving in posterior teeth of 35 nineteenth century Australian aboriginal skulls is due to sinew processing as well. Since the lesions observed in these specimens are similar to those reported in other populations, Brown and Molnar suggest a common etiology for interproximal grooving in posterior teeth (see also Eckhardt, 1990). This suggestion was contested by Frayer (1991), who exposes some problems with accepting the fiber or sinew processing as the etiology of interproximal grooving in posterior teeth. One of these problems concerns the shape and extension of the grooves. If sinew or fiber are drawn back and forth between the interdental spaces of posterior teeth, one would expect to find wear grooves extending across the entire mesial and distal surfaces, from the mesial/distal-buccal corner to the mesial/distal-lingual one. However, we have never observed an interproximal groove exhibiting this appearance. In contrast, interproximal grooving in posterior teeth is usually restricted to a part of the mesial and distal surfaces, and the grooves are typically assymetrical in shape (see also Frayer 1991's comments).

Closely related to these observations, one additional argument to discount the sinew or fiber processing hypothesis concerns the location pattern of grooves affecting the contiguous mesial and distal surfaces of two adjacent teeth. The usual pattern that we observed in Canarian aboriginals (Bermúdez de Castro and Arsuaga, 1983), as well as in the north African Mesolithic individuals

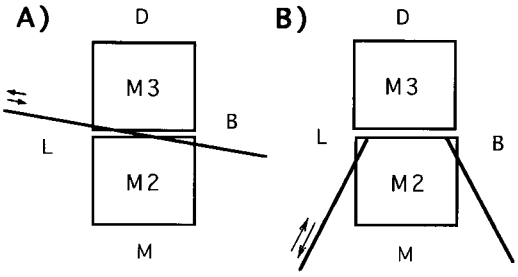

Fig. 4. Scheme showing the probable way of insertion of a probe (**A**), or a fiber or sinew (**B**) between the second (M2) and third (M3) molars. There are obvious difficulties in determining the motion of a sinew or fiber held and tightened with both hands as in A. B, buccal; D, distal; L, lingual; M, mesial.

from Taforalt and Afalou (Bermúdez de Castro and Pérez, 1986), is characterized by the presence of an interproximal groove affecting the buccal-distal corner of the UM2, whereas the UM3 exhibits interproximal wear either on the middle zone of the lingual surface, or on the mesial-lingual corner. An identical pattern was also observed by Ubelaker et al. (1969) and Berryman et al. (1979) in their respective studies of American Indians. This pattern implicates the oblique penetration of an object between the contiguous surfaces of the two upper molars, due to their position into the oral cavity. A similar oblique direction of the groove axis, though with different location patterns, is observed in the M1 and M2 of the mandible AT-888, and in the M1, M2, and M3 of the maxillary fragment AT 1130. Berryman et al. (1979) illustrates in their Figure 2 the presumed angle of insertion of dental probes, which would vary with the position of the tooth and the flexibility of the lips and cheeks. If the objects are not rigid (i.e., fibers or sinews) they ought to be held and tightened with both hands during its passage through the interdental spaces. An oblique penetration of fibers or sinews in such a situation (e.g., Fig. 4A) is simply impossible. The more logical motion of fibrous material or sinews as depicted in Figure 4B would produce an artificial wear preferently on the distal surfaces.

Finally, a question for those scholars inclined to accept the fiber or sinew hypothesis is why are the lesions limited to the posterior teeth in most human groups, when the anterior teeth seem more suitable for this kind of activity? We agree with Formicola (1991) that different appearances of interproximal grooving may have different etiologies, and that the position in the dental arcade, as well as the location pattern of the grooves, are important factors to consider previous to hypothesizing about the etiology of interproximal grooving in particular human samples. We believe that the most reasonable explanation for the artificial wear grooves observed in the Atapuerca-SH hominids is the antemortem passing of thin, hard, and inflexible (or semirigid) objects between teeth. The formation of the grooves was undoubtedly favored by the abrasive action of dietary grit. Whether these objects were dental probes used for cleaning the interdental spaces, for therapeutic palliative purposes, or for other reasons, may be a matter for further discussion.

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